Two Species of *Caligus* (Copepoda, Caligidae) from Australian Waters, with a Description of Some Developmental Stages[1]

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ABSTRACT: Adult females, males, and five developmental stages of *Caligus epidemicus* n. sp. are described from material collected from bream (*Mylio butcheri* Munro, 1949) and mullet (*Mugil cephalus* L.; *Alorichetta forsteri* Cuv. and Val., 1836; *Liza argentea* Quoy and Gaimard, 1825; and *Myxus elongans* Gunther, 1861) during a population explosion of the parasite in the lower Mitchell River area, Victoria, Australia, associated with a period of high temperature and salinity; the adults can be distinguished from other species of *Caligus* by the possession of spines immediately posterior to first maxillae and to the interpodal plate of the first pereiopods, by abbreviated appearance of posterior part of body and by the rather short seta on inner distal angle of first pereiopod. *Caligus elongatus* Nordmann, 1832, is recorded from *Eubalichthys moaicus* (Ramsay and Ogilby, 1888) for the first time, from Port Hacking.

THE MATERIAL DESCRIBED in this paper comes from two sources. The first group of 21 adult *Caligus* females, 22 adult males, 27 juveniles, and 49 copepodites was collected by Mr. G. H. Arnott from bream and mullet in the lower Mitchell River, Victoria and was forwarded to me by Dr. I. A. E. Bayly of Monash University, Victoria. Mr. Arnott and Dr. Bayly noted large numbers of the parasite on bream and mullet and in plankton samples in the lower Mitchell River, Victoria Lakes region of Victoria, Australia, from January to March 1968, at a time of severe drought, with water temperatures ranging from 14.5° C to 21.8° C, and salinity from 4.5 parts per thousand to 28 parts per thousand in the affected areas. In February fish were in such poor condition and infection rates so high that the situation was reported in the *Melbourne Herald*. By May the caligid was no longer being found in plankton samples. This material is described as a new species, *Caligus epidemicus*. Because there are so few descriptions of the development of species of *Caligus*, some of the more distinct developmental stages are described in detail.

The second group consists of four females and one male of *C. elongatus* taken from a balistid, *Eubalichthys moaicus* (Ramsay and Ogilby, 1888) (host determined by I. S. R. Munro), which was found dead floating at the surface of the entrance to Port Hacking, one-half mile off Cronulla Beach, on August 7, 1969. These animals were sent by Dr. R. Hammond, C.S.I.R.O., Division of Fisheries and Oceanography, Cronulla, New South Wales, to Dr. Z. Kabata of Fisheries Research Board of Canada, Nanaimo, British Columbia, who, in turn, gave them to me.

Caligus epidemicus n. sp.

Type Material

The type specimen is deposited with the Australian Museum, Sydney, as Australian Museum Number P 17622, and the paratypes as Australian Museum Number P 17623.

Type Locality

It was found in the lower Mitchell River, Victoria, Australia.

Hosts

The host animals are bream (*Mylio butcheri* Munro, 1949) and mullet (*Mugil cephalus* L., *Alorichetta forsteri* Cuv. and Val., 1836, *Liza*

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argentea Quoy and Gaimard, 1825, *Myxus elongans* Gunther, 1861).

Description

ADULT FEMALE: The overall length of the adult female (Figs. 1–16) is 2.46 to 2.85 mm (2.66 mm).[3]

Cephalothorax: The cephalothorax is as wide as long—1.69 to 1.99 mm (1.88 mm) × 1.61 to 2.02 mm (1.87 mm). Frontal area length one-fifth width 0.17 to 0.22 mm (0.19 mm), anterior margin slightly curved, bearing the anterior suckers which are 0.15 to 0.18 mm (0.17 mm) in diameter, laterally. Lateral margins of cephalothorax forming an entire curve with outer posterior region of posterior sinuses, bearing a narrow flange. Anterior and posterior median areas more than half cephalothorax width[4]; anterior median area limited laterally by sublinear grooves which diverge slightly anteriorly; posterior median area delimited by grooves which curve medially anteriorly and then curve anteriorly, joined in the midline by a short transverse groove which is indistinct in some specimens. Lateral margin of the area projecting posteriorly as lateral margins of posterior sinuses, separated from lateral areas for a short distance posteriorly, and projecting as processes posteromedially into the sinus. These projections have a small flange on their free margin. Eyes on midline two-sevenths distance from anterior margin.

Fourth Segment: The fourth segment is freely articulated, width twice length, 0.15 to 0.30 mm (0.21 mm) × 0.32 to 0.48 mm (0.43 mm), anterior and posterior margins sublinear, rounded laterally.

Genital Segment: Length is two-thirds width, 0.54 to 0.67 mm (0.59 mm) × 0.87 to 1.01 mm (0.93 mm), anterior and posterior margins sublinear, anterior and posterior angles broadly rounded, nearly forming a continuous curve with the lateral margins. The posterior margin projects posteriorly as two small semicircular platelike structures dorsal to the egg strings.

Abdomen: The abdomen (Fig. 16) is a little wider than long, 0.19 to 0.26 mm (0.23 mm) × 0.22 to 0.28 mm (0.26 mm), anterior and lateral margins sublinear, posterior margins broadly curved, and bearing the anal laminae. Abdomen has two groups of three small spines placed ventrally midway between lateral margin and midline.

Anal Laminae: The anal laminae (Fig. 16) are wider than long, 0.04 to 0.05 mm × 0.06 to 0.07 mm, anterior margins sublinear, lateral and posterior margins united in an entire curve (Fig. 16). Posterior margin bearing a small posterolaterally-directed plumose seta on inner distal region, three long plumose setae on distal region, and one or two plumose setae on outer distal region. Although all male and larval specimens had two plumose setae on outer distal region three females were observed in which these had been lost on both sides either during development or accidentally.

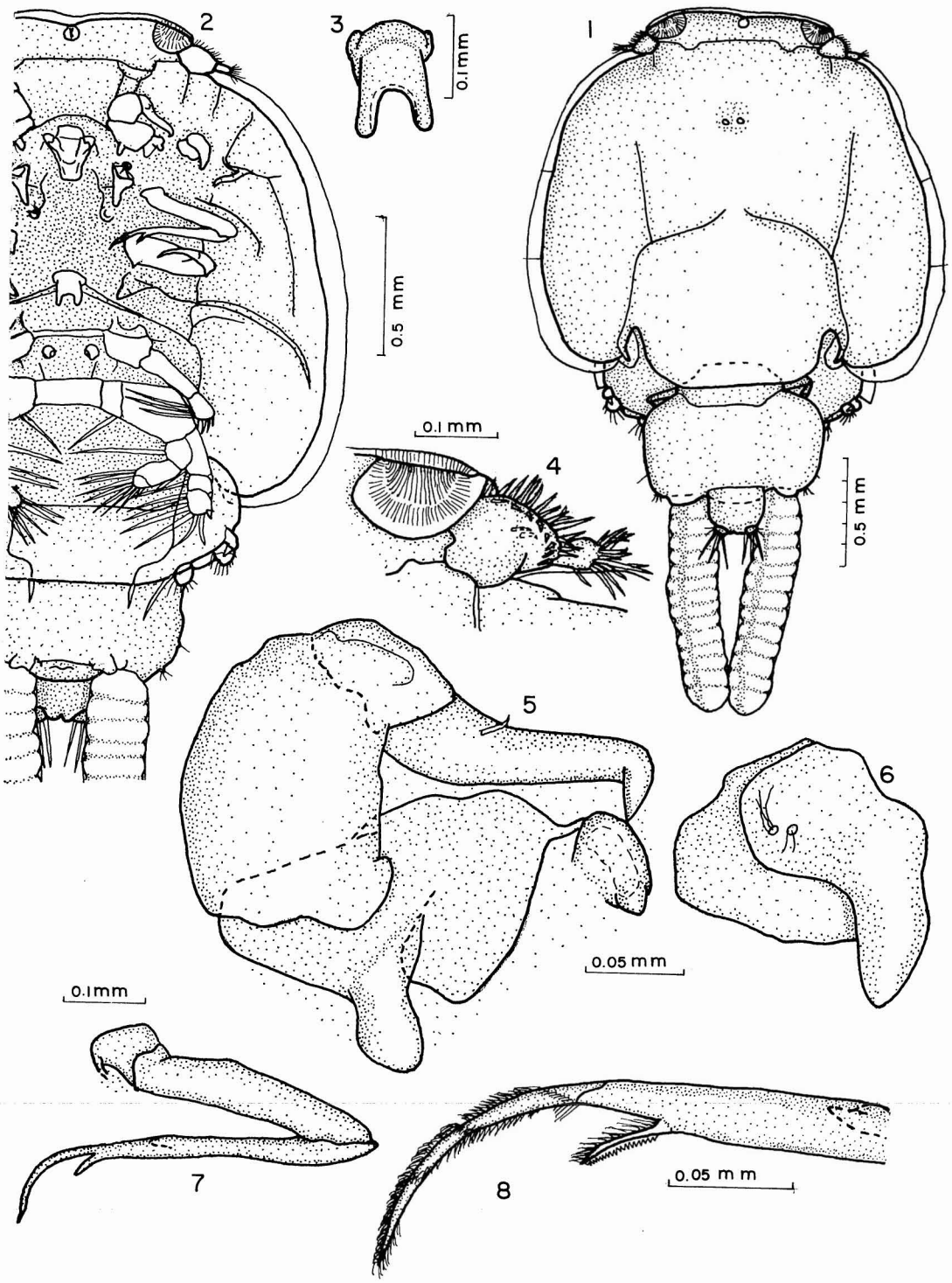
Egg Strings: These are 0.69 to 1.29 mm, containing between six and 18 eggs per string, most specimens with from 12 to 16 eggs per string.

First Antenna: The first antenna (Fig. 4) is composed of two segments, first segment twice length of second, a little longer than wide, narrowing and rounded distally, with 25 plumose setae on outer and distal margins, mostly plumose but two naked, and a further two setae on dorsal surface. Second segment, width two-thirds length, rounded distally, with eight setae on outer distal area and five longer setae on inner distal area, and a further single seta on inner margin two-thirds distance from proximal margin.

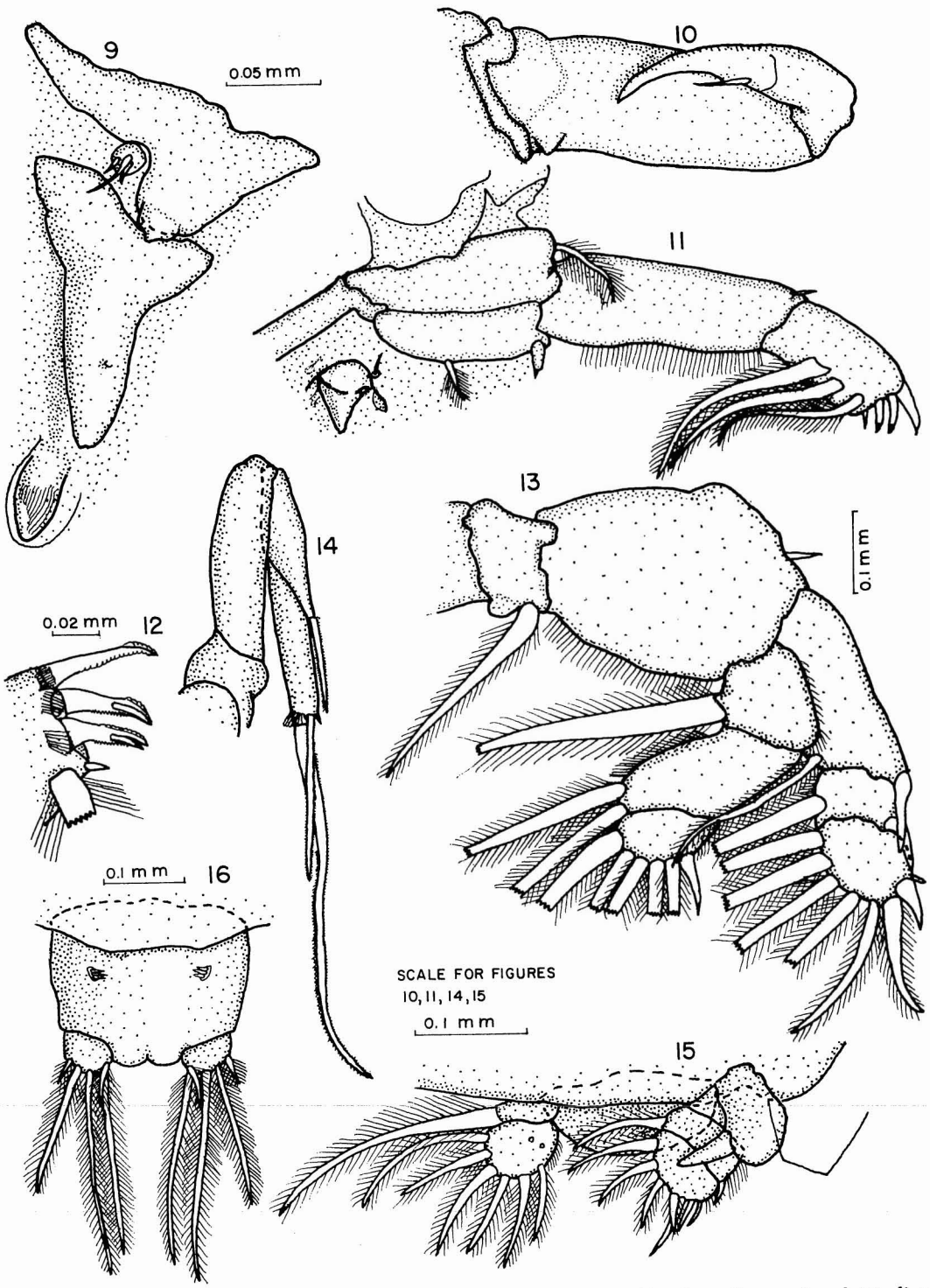
Second Antenna: The second antenna (Fig. 5) is borne on a large subtriangular base, which has a large blunt posteriorly-directed spine just medial to posterior apex, and is associated with a subovate raised area lying lateral to it. This area has a short blunt spinelike projection posteriorly. First part of antenna subequal in length to second, width two-thirds length, medial margin an entire curve, longer than less regular outer margin. Second segment, basal width two-

[3] All measurements are given as minimum-maximum (average), and are from 10 specimens unless some other number is specified.

[4] The terms "median anterior" and "median posterior" are used rather than the more widely used "cephalic" and "thoracic," because the maxillipeds, which are regarded as thoracic appendages in Crustacea, are associated with the so-called "cephalic" area.



FIGS. 1–8. *Caligus epidemicus* n. sp. Female. *1*, dorsal habitus. *2*, ventral habitus. *3*, sternal furca. *4*, first antenna, ventral. *5*, second antenna. *6*, postantennary spine. *7*, second maxilla. *8*, distal extremity of second maxilla.



FIGS. 9–16. *Caligus epidemicus* n. sp. Female. *9*, first maxilla. *10*, maxilliped. *11*, first pereiopod. *12*, distal extremity of first pereiopod. *13*, second pereiopod. *14*, fourth pereiopod. *15*, third pereiopod. *16*, abdomen and anal laminae.

sevenths length, narrowing gradually distally, proximal two-thirds curved in a plane with ventral surface of cephalothorax, distal third curving ventrally, a short seta arises near anterior margin just proximal to midpoint.

Postantennary Spine: The postantennary spine (Fig. 6) arises from a small but distinct base, basal width half length, curving laterally then posteriorly, narrowing gradually and then rapidly to a blunt point distally.

Mouthtube: This measures 0.03 mm in length, as wide as long, narrowing distally.

First Maxilla: The first maxilla (Fig. 9) has a subtriangular anterior plate, medial angle extended, posterior angle rounded, bearing a semicircular swollen area with a short blunt spinous medial projection. The middle structure consists of three setules borne on a round base, the middle setule twice length of setules on either side. The large spinous posterior portion has a basal width two-thirds length of spine, spine narrows suddenly immediately above base, then more gradually to a bluntly rounded distal termination. Spine has a minute circular raised area midway along region above base.

Immediately posterior to first maxilla is a small blunt spine, one-third length of posterior spine of maxilla, basal width half length, distal termination bluntly rounded, posteriorly directed, with longitudinal striations along medial section.

Second Maxilla: The second maxilla (Figs. 7–8) comprises two parts, first part two-thirds as long as second; slender. Second part even more slender than first, with a small membrane on dorsal surface near midpoint, a spinelike extension constituting one-third length, a smaller outer extension one-third length of larger extension and arising near its base, with membranes on both margins, the outer membrane less deeply serrate than the inner. Outer extension with four longitudinal, deeply serrate membranes which often form a spiral pattern when the limb twists during preservation.

Maxilliped: The maxilliped (Fig. 10) comprises two parts. First part width one-third length, narrowing slightly and rounded distally with a short spinelike projection near base. Subchela three-quarters length of first part, basal width one-quarter length, narrowing steadily to a sharp point distally, sharply curved back ventrally against first, with a seta one-fifth length of segment near midpoint on posterior margin.

First Pereiopod: First pereiopod is shown in Figs. 11–12. Protopod width is three-quarters length, angles rounded, somewhat swollen distally, with a pinnate seta on rounded outer distal angle, a further pinnate seta near midpoint of posterior margin, and a small endopod one-quarter length of protopod, on distal posterior angle. Endopod basal width two-fifths length, narrowing sharply distally so that it appears to bear a spine, but this spinous area on closer inspection seems to be part of the segment.

Exopod half as long again as protopod, of two segments. First segment twice length of second, width half length, with cilia on inner margin, and a spine on outer distal angle. Second segment width two-thirds length, with three plumose setae on inner margin, and three spines and a seta on distal margin, the spines reducing in size from the outermost to the innermost. The outermost spine bears a serrate comb over the distal third of its outer margin and the inner margin is serrate for the distal three-quarters of its length; the second spine is similarly armed although the serrations on the inner margin are sharper, and in addition the spine is bifid over its distal third; the third spine is similar to the second but smaller, and the inner seta is very small, one-third length of third spine, and is simple in structure. The three large spines have pectinate membranes associated with their bases.

Immediately posterior to interpodal plates of first pereiopod and just medial to the pereiopod is a stout spinelike process one-third length of second joint of exopod of first pereiopod, as wide at base as long, narrowing rapidly to a sharp point. It has a setule on a small base, and a lacuna, lateral to it, the lacuna variable in position.

Second Pereiopod: Second pereiopod is illustrated in Fig. 13. Protopod composed of two fused segments. First segment one-quarter length of second, length two-thirds width, subrectangular, with a pinnate seta near inner distal angle. Second segment width two-thirds length, inner margin with long setules, outer

distal angle with a seta, and outer margin with a dorsally projecting membrane.

Exopod a little longer than endopod, second segment one-quarter length of first, two-thirds length of third. First segment subrectangular, width half length, with a stout spine on outer distal angle, a pinnate seta on inner distal angle and a dorsally projecting membrane along its outer margin. Second segment subrectangular, length two-thirds width, with spine on outer distal angle and pinnate seta near inner distal angle, third segment subsemicircular, as long as wide, with a stout spine and a fine spine on outer distal angle, and six pinnate setae on distal and inner margins.

Endopod, third segment a little shorter than first, half length of second. First segment as wide as long, outer distal angle broadly rounded and bearing setules, inner distal margin with a long seta. Second segment width half length, inner and outer margins with setules; inner distal angle extended and bearing two pinnate setae. Third segment subsemicircular, proximal margin sublinear, length half width, with a spine on outer distal region, and five pinnate setae on inner and distal regions, and setules on the two free areas of margin not occupied by setae.

Third Pereiopod: Third pereiopod is illustrated in Fig. 15. Protopods are developed into aprons in the usual manner, united by the extended interpodal bar, two longitudinal ribs bearing pinnate setae on their posterior margins and the free margin with a membranous flange except where the rami are situated and anterolaterally where ridges form an adhesion pad.

Exopod well separated from endopod, of three segments. First segment swollen from base to outer margin, swollen section bearing a stout spine distally. Second segment length half width, with a row of setules on outer margin, a spine on outer distal angle, and a pinnate seta on inner distal angle. Third segment subsemicircular, length half width, with setules on outer region, three spines on outer distal region, and four pinnate setae on inner and distal regions.

Endopod separated from exopod by velum, as long as endopod, width twice length. Basal segment of endopod one-third length of second segment, length half width, with a stout pinnate seta on inner margin. Second segment rounded, as long as wide, with a row of setules on outer region and six pinnate setae on distal region.

Fourth Pereiopod: The fourth pereiopod (Fig. 14) comprises three parts, the second and third subequal in length, the first a little longer. First part width one-third length. Second part width one-third length, outer distal angle extended and bearing a long seta with spinules along either margin, spine reaching to end of third part. Third part width one-quarter length, the distal margin somewhat squarely truncate, with one very minute spine on outer distal angle, a spine as long as segment next to it, armed, like spine on second segment, with long spinules. Next to this spine on inner distal angle is a further spine twice its length, with a pectinate flange at base. The outer margin has minute spines, inner margin is armed over distal half of length with broad setules.

Fifth Pereiopod: This is vestigial, consisting of two slight swellings on ventral surface of genital segment near lateral margin, the more anterior carries a single seta, the more posterior with three setae.

MALE: The overall length of the adult male (Figs. 17–26) is 1.52 to 1.72 mm (1.59 mm).

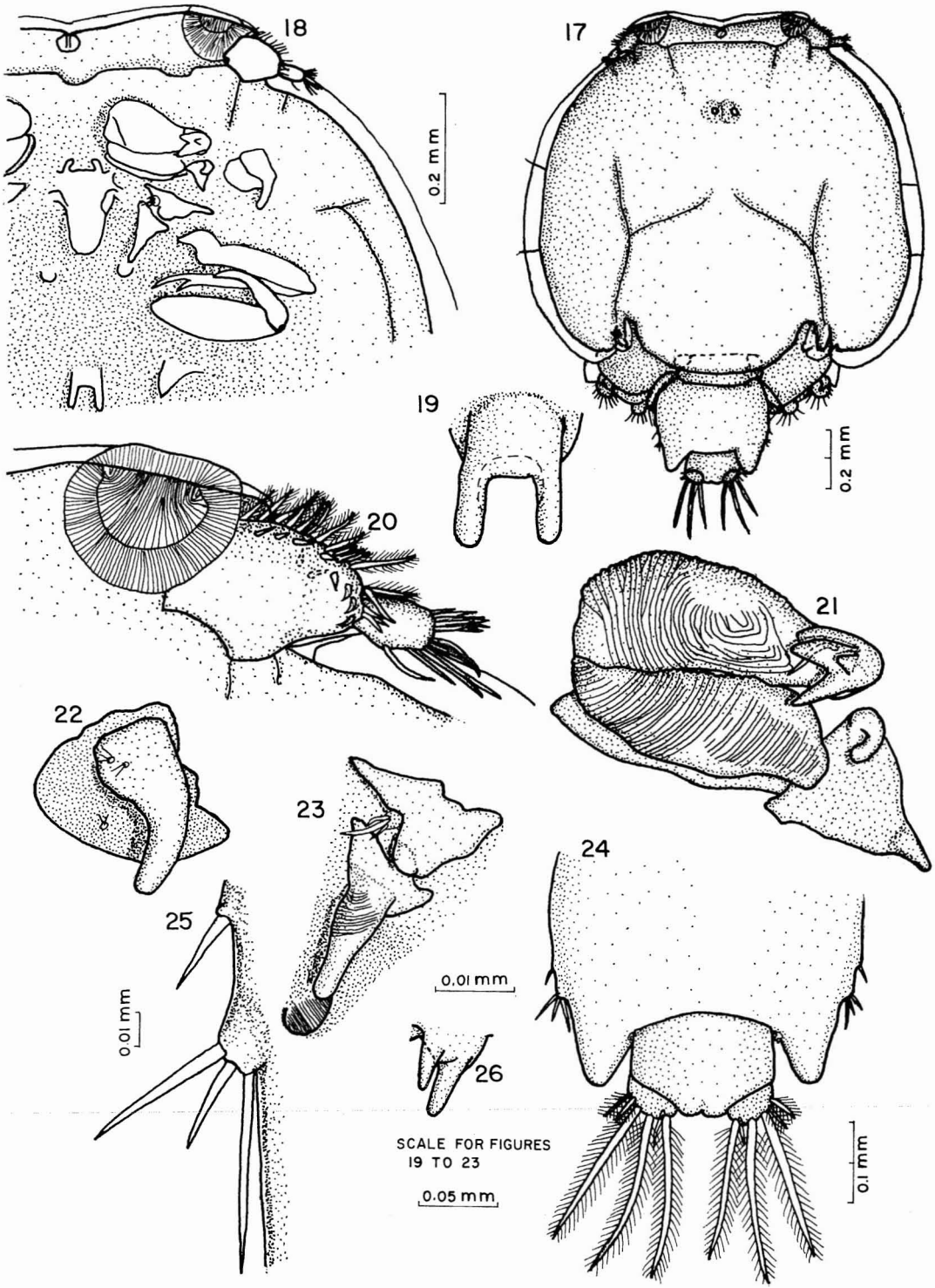
Cephalothorax: The cephalothorax is of the same general form as in female, frontal plate 0.11 to 0.16 mm (0.12 mm) × 0.50 to 0.63 mm (0.57 mm); overall length and width 1.08 to 1.25 mm (1.21 mm).

Fourth Thoracic Segment: This is of same general form as in female, 0.09 to 0.14 mm (0.12 mm) × 0.21 to 0.31 mm (0.27 mm).

Genital Segment: The genital segment is subrectangular, 0.30 to 0.38 mm (0.35 mm) × 0.37 to 0.44 mm (0.41 mm); anterior angles rounded, posterior angles projected posteriorly almost to tip of abdomen.

Abdomen: Abdomen (Fig. 24) subrectangular, 0.10 to 0.15 mm (0.12 mm) × 0.18 to 0.20 mm (0.19 mm) posterior margin somewhat curved.

Anal Laminae: These are subsemicircular, 0.03 to 0.05 mm (0.04 mm) × 0.05 to 0.07 mm (0.06 mm) with two small plumose setae



FIGS. 17–26. *Caligus epidemicus* n. sp. Male. *17,* dorsal habitus. *18,* ventral habitus. *19,* sternal furca. *20,* first antenna, ventral view. *21,* second antenna. *22,*postantennary spine. *23,* first maxilla. *24,* posterior extremity of body. *25,* fifth pereiopod. *26,* sixth pereiopod (?).

on outer posterior region, three long plumose setae on posterior region, and one short seta near inner posterior area.

First Antenna: The first antenna (Fig. 20) is of same general form as in female.

Second Antenna: The second antenna is composed of three parts, associated with a stout base, which in turn is associated with a subtriangular raised plate near its inner margin. The associated plate has a spine on inner posterior angle, and a raised kidney-shaped area on its anterior angle. First part of antenna as long as second, width two-fifths length, the ventral surface covered in transverse striations. Second part width two-fifths length, narrowing to half this width distally, with fine striations over much of surface, the striations becoming partially concentric distally. Third part one-third length of second, basal width half length, the distal quarter forked, with a further stout branch half length of distal fork arising just beyond midpoint of outer margin, inner margin with a seta one-quarter distance from base.

Postantennary Spine: The postantennary spine (Fig. 22) has outer margin forming an entire curve, tip somewhat abruptly truncated.

Mouthtube: Mouthtube appears as in female.

Maxilla: Maxilla (Fig. 23) has basal region as in female, but with posterior spine more slender basally, rounded posteriorly, and with transverse striations about midpoint.

The male, like the female, carries a raised area just posterior to the maxilla but in this case the striations on this area are transverse.

Maxilliped: Maxilliped appears as in female except for a small conical pad, rounded distally, placed one-third of distance from distal margin of first segment, and a reduction in the relative size of the spinous process found near the base on the female.

Sternal Furca and First Five Pereiopods: The sternal furca (Fig. 19) and first five pereiopods are similar to those of female.

Sixth Pereiopod: The sixth pereiopod (Fig. 26) is represented by a minute pair of spines on a slight raised boss on posterior lateral margin of genital segment just medial to the extended posterior angle (Fig. 26).

LARVAL AND JUVENILE FORMS: Since the larval material was not obtained by hatching the specimens, I have tried to avoid confusion of different stages and of juvenile males and females by selecting only those types that seemed to be very distinct. These consisted of five types (labelled *A–E* in Figs. 27–72). The first of these, *A,* is clearly a copepodite and *B–E* are "chalimus" stages.

Some of the difficulty in separating distinct developmental stages is undoubtedly due to the fact that these animals were taken from a population which was undergoing a population explosion at the time. There is considerable evidence from other animal populations to show that under these circumstances atypical and deformed types which would not normally survive are present in the population (e.g., Ford, 1964, p. 14).

In the following account the morphology of the body of the various stages is discussed first, and then the development of each appendage is considered separately. Measurements of the various parts of the body, expressed in millimeters and as a function of total length, are given in Tables 1–4.

Stage A: (See Fig. 27.) In the copepodite the cephalothorax is already united with the first leg-bearing segment. The cephalothorax is rounded anteriorly with no sign of a frontal area, lateral margins entire curves. Posterior margin sublinear medially, subtending two pairs of grooves anteriorly along the dorsal surface, both subparallel to the margin, the outermost pair extending anteriorly for one-third length of cephalothorax, the inner pair half this length, the inner pair with a narrow sinus at the point at which they arise on posterior margin. The posterior margin expands posteriorly as two spinelike structures just lateral to its point of attachment to second segment. Second and third segments distinct and freely articulated. Fourth segment apparently distinguishable from the combined genital segment and abdomen by a shallow groove. Anal laminae already similar in form and armament to those of the adult (Fig. 27).

Stage B: (See Fig. 28.) The smallest and

TABLE 1

AVERAGE LENGTHS IN DEVELOPMENTAL STAGES OF *Caligus epidemicus*
(in mm)

	STAGE				
	A	*B*	*C*	*D*	*E*
Number of Specimens Measured	10	1	2	4	7
Total Length	0.45	0.88	0.98	1.18	1.76
Frontal Area		0.12	0.12	0.09	0.15
Anterior Sucker (diam.)		0.07	0.10	0.11	0.14
Cephalothorax	0.29	0.53	0.57	0.82	1.44
Second Segment	0.06	0.07	0.11	0.17	
Third Segment	0.04	0.11	0.15	0.17	
Fourth Segment	0.03	0.06	0.08	0.08	0.14
Genital Segment	0.05	0.07	0.11	0.24	0.20
Abdomen		0.09	0.07	0.10	0.17
Anal Laminae	0.02	0.03	0.03	0.04	0.04

TABLE 2

AVERAGE WIDTHS IN DEVELOPMENTAL STAGES OF *Caligus epidemicus*
(in mm)

	STAGE				
	A	*B*	*C*	*D*	*E*
Frontal Area		0.25	0.26	0.35	0.62
Cephalothorax	0.17	0.38	0.45	0.78	1.26
Second Segment	0.11	0.23	0.24	0.38	
Third Segment	0.09	0.20	0.23	0.38	
Fourth Segment	0.08	0.13	0.17	0.18	0.32
Genital Segment	0.07	0.14	0.20	0.29	0.45
Abdomen		0.07	0.12	0.16	0.23
Anal Laminae	0.03	0.03	0.04	0.05	0.06

least developed of the chalimus stages possesses a well-developed frontal filament, indistinct anterior suckers on the anterolateral part of the cephalothorax, which narrows slightly immediately behind the anterior suckers and then expands so that the remainder of the lateral margins are entire curves. This narrowing behind the anterior suckers is continued as a groove across the dorsal surface which appears to mark what will later be the frontal area. Posterior margin of cephalothorax concave, apparently becoming more solidly fused to the second segment. The lateral grooves which originate from the posterior margin in the copepodite have been lost, but the grooves which apparently delimit the lateral margins of the fused first segment are still clearly visible and remain so even in the adult. Third segment still apparently freely articulated with the second anteriorly, and with the fourth segment. Fourth segment still fused with genital segment, but still distinguishable from it by a groove. Genital segment with a well-defined groove about two-thirds of distance from anterior margin, slightly more swollen than the abdomen with which it is still completely fused (Fig. 28).

Stage C: (See Fig. 29.) The second distinct chalimus stage has a cephalothorax in which the anterior margin has become slightly flattened, the anterior suckers are more clearly distinct than in Stage *B*, the groove posterior to the anterior suckers is also more distinct although a completely separate anterior area is not yet present. The cephalothorax now bears a flange on either side, which extends around the posterior angles to terminate in the sinus which is

TABLE 3

LENGTHS DIVIDED BY TOTAL LENGTHS IN DEVELOPMENTAL STAGES OF *Caligus epidemicus*

	STAGE						
	A	*B*	*C*	*D*	ADULT MALE	*E*	ADULT FEMALE
Anterior Sucker (diam.)		0.08	0.10	0.09	0.07	0.08	0.06
Frontal Area		0.14	0.12	0.08	0.08	0.09	0.07
Cephalothorax	0.67	0.60	0.57	0.70	0.76	0.82	0.71
Second Segment	0.13	0.08	0.11	0.14			
Third Segment	0.09	0.13	0.15	0.14	0.39	0.37	0.34
Fourth Segment	0.07	0.07	0.08	0.07	0.08	0.08	0.08
Genital Segment	0.11	0.08	0.11	0.21	0.22	0.11	0.22
Abdomen		0.10	0.07	0.08	0.09	0.09	0.09
Anal Laminae	0.04	0.04	0.03	0.03	0.03	0.02	0.02

TABLE 4

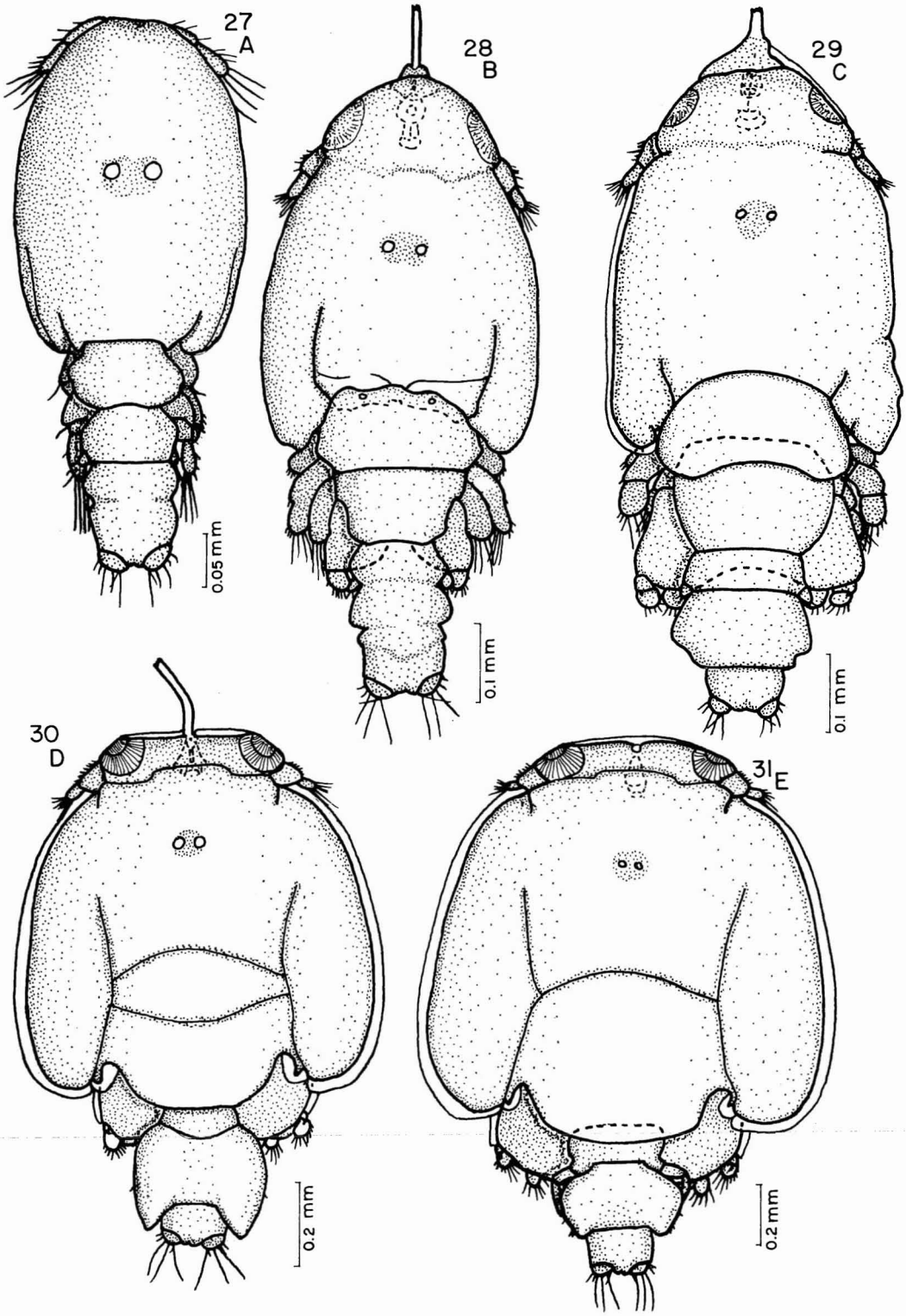
WIDTH DIVIDED BY TOTAL LENGTH IN DEVELOPMENTAL STAGES OF *Caligus epidemicus*

	STAGE						
	A	*B*	*C*	*D*	ADULT MALE	*E*	ADULT FEMALE
Frontal Area		0.28	0.27	0.35	0.36	0.35	0.35
Cephalothorax	0.40	0.43	0.45	0.66	0.76	0.72	0.70
Second Segment	0.24	0.26	0.24	0.32			
Third Segment	0.20	0.23	0.23	0.32	0.44	0.44	0.40
Fourth Segment	0.18	0.15	0.17	0.15	0.17	0.18	0.13
Genital Segment	0.16	0.16	0.20	0.26	0.26	0.25	0.35
Abdomen		0.08	0.12	0.14	0.12	0.13	0.10
Anal Laminae	0.07	0.03	0.04	0.04	0.04	0.03	0.03

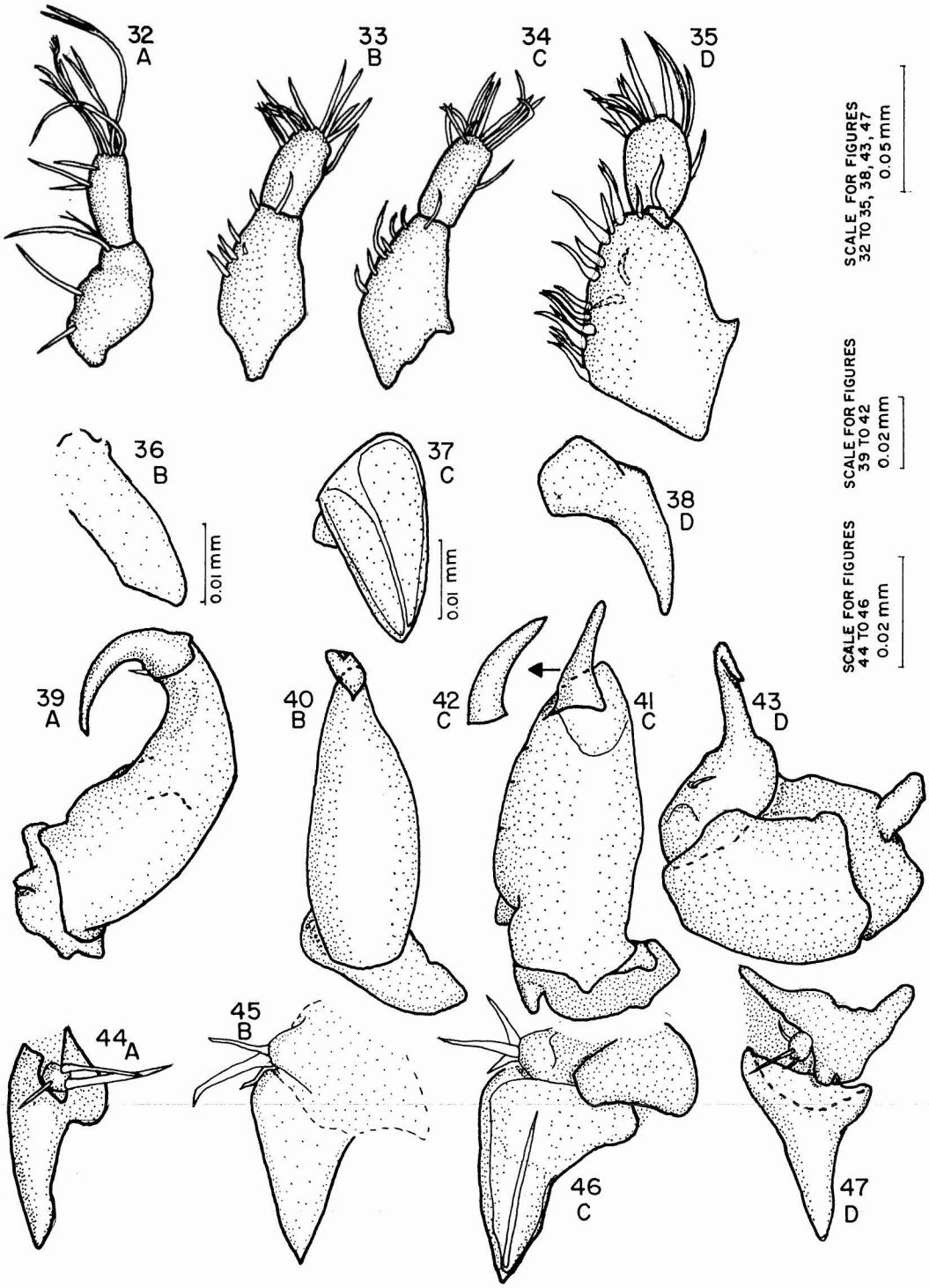
formed by the lateral margin of the cephalothorax and the second segment. The second segment now seems to be largely fused with the cephalothorax, although it can still be distinguished by a clear anterior groove. Third segment still freely articulating. Fourth segment now distinct from genital segment, which in turn is distinct from the abdomen. The groove which occurred in the genital segment has now filled out although the anterior region of the segment is still more swollen than the posterior (Fig. 29).

Stage D: (See Fig. 30.) This stage has much in common with the adult male, except that it still possesses a frontal filament. In some specimens the third leg-bearing segment which has now become fused with the cephalothorax is still distinguishable by a transverse groove, which seems to disappear in the adult so that, in the adult, the transverse groove marking the anterior part of the median posterior area seems to be that which is formed at the junction of the second leg-bearing segment and the remainder of the cephalothorax. This stage can also be distinguished completely from the adult male by the form of the second antenna which more closely resembles that of the adult female. It would not be safe to assume that specimens at this stage can be identified as being males or females. It seems likely, in fact, that both male and female go through a very similar developmental stage which is close in appearance to the adult male. The female then continues development to a further juvenile stage (Fig. 30).

Stage E: (See Fig. 31.) Specimens at this stage resemble the adult female in almost all characteristics, except that many of the specimens at this stage possess a frontal filament



FIGS. 27–31. *Caligus epidemicus* n. sp. Developmental stages. *27,* copepodite, stage *A. 28–31,* "chalimus" stages, stages *B–E.*



FIGS. 32–47. *Caligus epidemicus* n. sp. Developmental stages. *32–35,* first antenna, stages *A–D. 36–38,* postantennary spine, stages *B–D. 39–43,* second antenna, stages *A–D. 44–47,* first maxilla, stages *A–D.*

which is lacking in most but not all of the adult females and the genital segment at this stage is much shorter and narrower than in the adult. The appendages in *E* are similar to those of the adult female (Fig. 31).

First Antenna: The most striking changes in the first antenna (Figs. 32–35) take place in the first segment and in the setation. The second segment becomes slightly more swollen in the course of development but otherwise changes very little. The first segment, however, more than doubles its width and nearly doubles its length by the time the animal is adult. This change takes place gradually through stages *B* and *C* and more markedly between stages *C* and *D*. In stage *A* the first segment bears only four setae—two on the outer distal angle, one near the outer proximal angle, and another on the outer margin—one of the setae on the outer distal angle being split toward the tip.[5] In stages *B* and *C* there are still two setae near or on the distal margin but neither of these is split; the outer margin bears five setae. In stage *D* the outer margin now bears 11 setae, the distal margin five, and there are two other setae on the dorsal surface. The second segment in stage *A* has six setae on the distal margin of which three are slit near the tip, and has a further three setae on the outer distal area. In stage *B* the second segment has a group of six setae on the outer distal area, a further group of four setae on the inner distal area, and a single seta on the midpoint of inner margin. Stage *C* is similarly armed except for an additional small seta on the outer distal area. Stage *D* has four setae on the inner distal region and seven rather shorter setae on the outer distal region as well as a single seta on the midpoint of the inner margin. By stage *E* the adult condition of five setae on the inner distal region and nine setae on the outer distal region has been reached, possibly by the splitting of one seta in each group.

Postantennary Spine: This spine (Figs. 36–38) is absent in stage *A*, making its first appearance in stage *B* as a flattened structure which narrows over its distal third to a blunt point. By stage *C* it has become a much heavier structure, subtriangular in shape, the lateral margins slightly curved, with what appears to be a central canal or inner thickening running medially through the structure. In stage *D* the spine has become very similar to that found in the adult male and female although it is a little narrower.

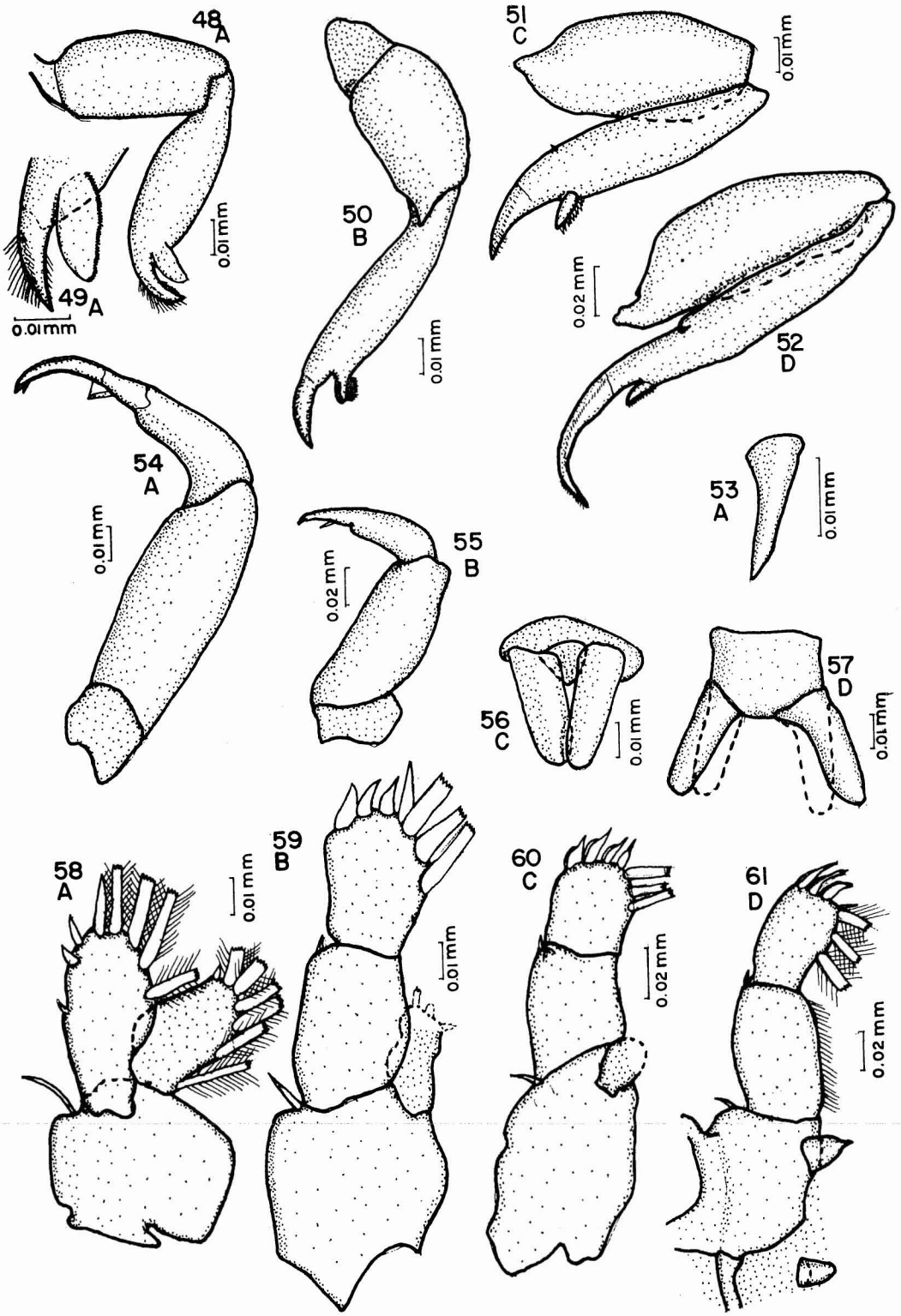
Second Antenna: The second antenna (Figs. 39–43) in the copepodite resembles strongly the maxilliped of the adult. It is subchelate with a strongly flexed and sharp subchela two-thirds length of first part, which has a small spine near its base. In stage *B* the subchela is very much reduced, now only one-sixth length of basal part, but is larger again in stage *C* where it is one-third the length of the basal part. In stage *D* the subchela is now longer than the basal part and curves twice, once anteriorly and once ventrally, as in the adult, and has a seta near its base as in the adult, but is still rather smaller and lighter in structure. There is no indication that the second antenna can be used as a means of distinguishing males and females among the larval forms. The plate at the base of the first segment bears a spinous structure in stages *A, C,* and *D* but seems to lack this structure in stage *B*.

Maxilla: The maxilla (Figs. 44–47) is already similar to that of the adult in the copepodite, except that it lacks the subtriangular plate. However, in stage *B* the posterior spine becomes much wider than is found in the adult and this widening persists in stage *C*. Also in stage *C* the spine appears to have a central canal or thickening similar to that found in the postantennary spine at this stage of development. By stage *D* the spine is again similar to the adult form, intermediate in shape between that of the male and female. The subtriangular plate associated with the maxilla appears first in stage *B* but is not well defined until stage *C* where it has a somewhat rounded form; in stage *D* it approaches its adult shape.

In the copepodite there is a large spine (Fig. 53) which is posterior to the maxillae, medial to and slightly anterior to the base of the maxilliped.

Second Maxilla: The second maxilla (Figs.

[5] In each case the number of setae given is the maximum found in the specimens examined. Even in these specimens some setae may have been lost.



FIGS. 48–61. *Caligus epidemicus* n. sp. Developmental stages. *48–52,* second maxilla, stages *A–D. 53,* postmaxillary spine, stage *A. 54–55,* maxilliped, stages *A–B. 56–57,* sternal furca, stages *C–D. 58–61,* first pereiopod, stages *A–D.*

48–51) is much stouter and shorter in the copepodite, basal segment width half length, second segment width one-third length, but it gradually becomes longer and more slender through the subsequent developmental stages to the long slender adult form. Changes also take place in the armament of the distal extensions, the longer outer extension having longitudinal rows of deeply serrate membranes; the inner extension is flattened in the copepodite, its anterior margin rounded, its posterior margin sublinear and serrated; in stage *B* it has broad setules on anterior and posterior margins; in stages *C* and *D* it has broad setules only on the posterior margin. Stage *C* has a small spine on the outer margin of second segment opposite base of extensions, and stage *D* while lacking this spine has a spinelike projection from inner margin just proximal to this point. The other striking change in the second maxilla is in the relative lengths of the extensions, the outer extension being little longer than the inner in the copepodite but steadily increasing in relative length in each of the subsequent stages.

Maxilliped: The maxilliped in larval forms (Figs. 54–55) does not differ greatly from that of the adult, except that in the stages *A* and *D* the distal curvature of the subchela is not so pronounced, and there is a very small spine or spinous projection near the tip.

Sternal Furca: The sternal furca is absent in stages *A* and *B,* first appearing in stage *C* (Fig. 56) in which stage it is somewhat flattened in appearance; the two branches converge and overlap distally, and there appears to be a conical structure between the bases of the tines. In stage *D* (Fig. 57) the furca is closer to the adult form, but the angle of the tines to each other varies as though the structure had been crumpled and is still expanding.

First Pereiopod: The development of the first pereiopod (Figs. 58–61) is marked by a change from a clearly biramous limb, each ramus with one segment, to one in which the endopod is greatly reduced and the exopod has two segments. Changes also occur in the armament. In stage *A* the endopod is almost as large as the exopod, both are one-segmented, the exopod bears four spines on its outer distal region, the spines increasing in size from the most proximal to the most distal, and four pinnate setae on the inner distal region. The endopod bears a small spinous process on its outer distal angle and six pinnate setae over its distal and inner margins. In stage *B* the exopod is half as long again as in stage *A,* is clearly two-segmented, and has a small spine now present on outer distal angle of segment one, four spines on distal margin of segment two, of which the spine nearer inner distal angle is the longest, and three pinnate setae on inner distal area. The endopod is 40 percent narrower and a little shorter than in stage *A,* and its armament is much reduced, although this area is somewhat obscured in the specimens available. In stage *C* the three spines on distal margin now have flanges on their outer margins, and the seta on inner distal angle seems relatively smaller. Endopod is reduced yet further but again its distal margin is obscured in specimens at this stage and its armament is not clear in my specimens. In stage *D* the exopod is now largely in the adult form, except that the first segment of the exopod is still somewhat shorter than in the adult and the seta on the outer distal angle of the basipod is not as well developed. Some further reduction of the endopod, but no change in shape, is still to occur.

Second Pereiopod: The second pereiopod (Figs. 62–65) in stage *A* is biramous, each ramus one-segmented, the exopod with a small spine medially on outer margin, a further small spine on outer distal area next to which is a seta with setules on its inner margin, its outer margin serrate, and four pinnate setae on the rounded distal margin. The endopod bears a small spine on outer distal region and six plumose setae on its rounded distal and inner margins. In stage *B* both exopod and endopod are more elongate, there is a further spine on the outer distal region of exopod and a narrowing near midpoint of each ramus suggests the positions at which segmentation will occur. By stage *C* both rami are now two-segmented and are approaching the adult form except that the second and third segments of the ramus are still fused.

Third Pereiopod: The third pereiopod (Figs. 66–69) is present in stage *A* as a posterolateral

swelling on the third leg-bearing segment, the swelling tipped by one short, fine spine and a further longer, stouter spine. In stage *B* two rami are clearly developed, the outer ramus rounded with a spine on the midpoint of outer margin, a further spine on outer distal region, and four setae on distal and inner distal regions. Endopod also rounded, with four setae on inner and distal margins, the most proximal being the largest.

In stage *C* armament is as in *B,* but there is some sign of the division of exopod into two segments and endopod is clearly divided into two segments. In stage *D* this pereiopod is almost in the adult form except that the second and third segments of the exopod are still fused.

Fourth Pereiopod: The fourth pereiopod (Figs. 70–72) appears as posterolateral swellings on the area which is becoming differentiated as the fourth segment, this swelling bearing two setae distally. In stage *C* the swelling has become relatively longer and is clearly a one-segmented uniramous structure. In stage *D* the fourth pereiopod is now two segmented, the segments subequal in length, their widths two-thirds length, first segment with a single seta on outer distal angle, the seta two-thirds length of segment, second segment with a spine on midpoint of outer margin, and three spines on distal margin, the outermost half length of medial spine, innermost twice length of medial spine.

Discussion

Caligus epidemicus is very similar to *C. pageti* Russell, 1925, described from *Mugil capito* from Egypt. This latter species was later redescribed by Brian (1931 *a,* p. 119) as *C. argilasi,* a mistake he corrected later the same year (1931 *b,* p. 157), from specimens taken from *Mugil auratus* in Algerian waters. I have been unable to obtain specimens of *C. pageti* but the descriptions by Russell and Brian, together with further information given by Argilas (1931, p. 95), allow a comparison with the present material.

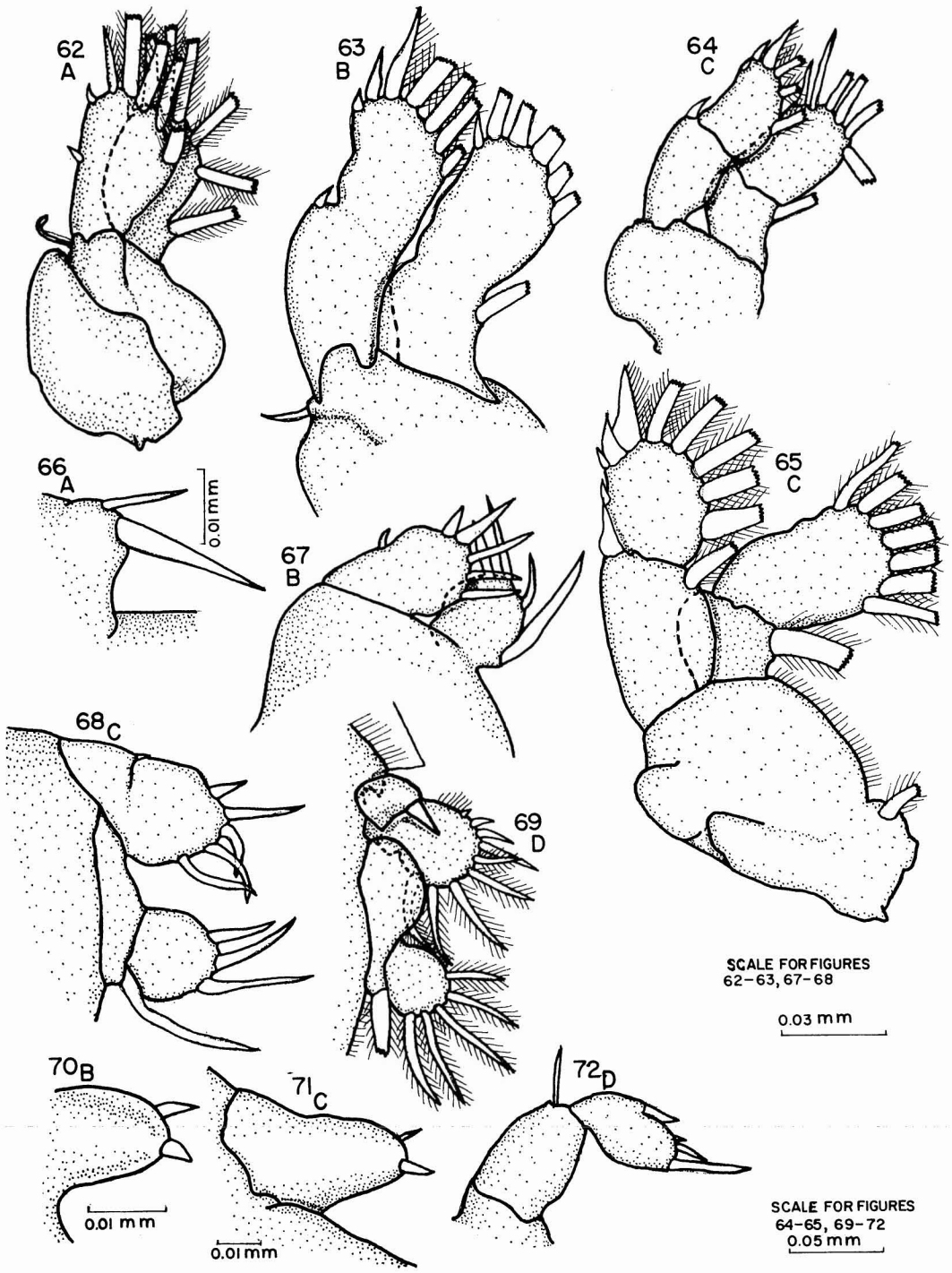
In the female of *C. pageti* the genital segment is two-fifths the cephalothoracic length and the abdomen is longer than wide. In all specimens of *C. epidemicus* the genital segment is one-third the cephalothoracic length or less and the abdomen as wide as long or wider. Similarly in the male the abdomen and genital segment tend to be relatively shorter in *C. epidemicus* giving them a more abbreviated appearance. Also, in *C. pageti* the seta on the inner distal angle of the distal exopod segment of the first pereiopod is longer than the terminal spines on the same segment, while in the present material it is shorter than the shortest of these spines; the former species has a lateral expansion of the branches of the sternal furca immediately above their base, but in *C. epidemicus* the lateral margins of these branches are subparallel; the vestigial fifth and sixth pereiopods are close together on the posterior angles of the genital segment of *C. pageti* and occur more anteriorly on the lateral margin of this segment in *C. epidemicus.*

This detailed consideration of the differences between these two species is required because of a number of striking similarities between them. They are found on related host fish; there is considerable similarity in general body form; and the form and armament of the fourth pereiopods, which are frequently of taxonomic interest in caligids, appear to be identical. From this the two species are closely related but the differences are too great for them to be considered conspecific.

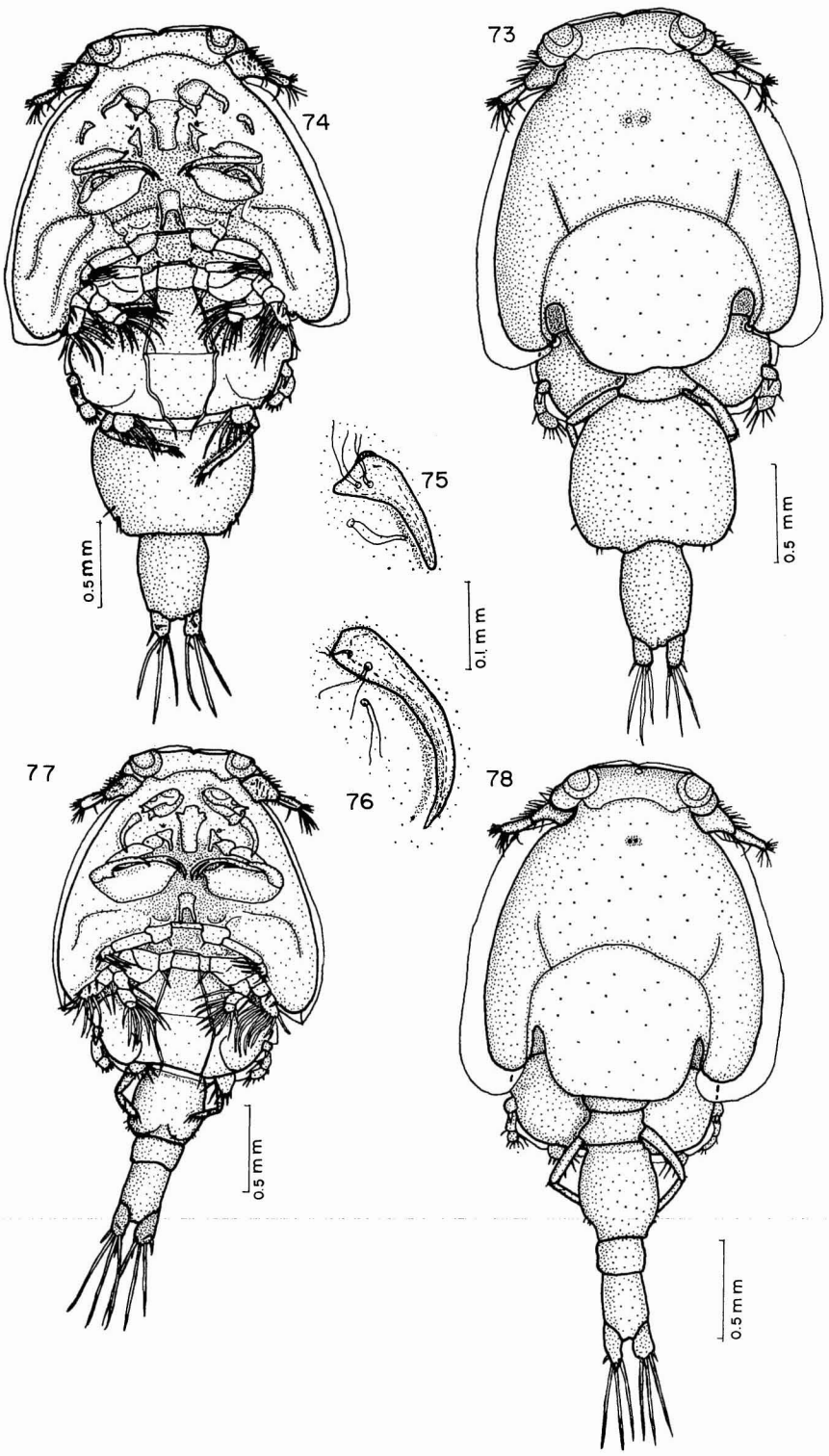
There may also be ecological similarities between the two species. Russell's specimens, like mine, were taken when the numbers of the parasite had risen to a level where damage to the host fish had become obvious (Russell, 1925, p. 616). In each case salinity was higher than normal for the area. Russell's specimens were taken from ponds at a fish farm on Lake Maryût at Mex, near Alexandria, which was fed by a salt spring which raised the salinity to 44 to 45 grams/liter (Russell, pers. comm.).

Development in the two species seems to proceed in a similar fashion, although Russell reports a two-segmented fourth pereiopod in the smallest chalimus stage, while in my specimens this limb does not have two segments until much later.

There are too few detailed descriptions of the development of members of the Caligidae to discuss how development in the present



FIGS. 62–72. *Caligus epidemicus* n. sp. Developmental stages. *62–64,* second pereipods, stages *A–D. 66–69,* third pereiopods, stages *A–D. 70–72,* fourth pereiopods, stages *B–D.*



FIGS. 73–78. *Caligus elongatus* Nordmann, 1832. Female. *73,* dorsal habitus. *74,* ventral habitus. *75,* postantennary spine, male. *76,* postantennary spine. *77,* ventral habitus. *78,* dorsal habitus.

TABLE 5

MEASUREMENTS OF *Caligus elongatus*
(in mm)

	FEMALE (average of four specimens)	MALE (one specimen)
Total Length	3.37	3.23
Frontal Plate	0.21 × 0.91	0.19 × 0.91
Anterior Sucker (diam.)	0.19	0.18
Cephalothorax	1.88 × 1.53	1.81 × 1.50
Fourth Segment	0.20 × 0.40	0.22 × 0.36
Genital Segment	0.75 × 0.76	0.51 × 0.42
Abdomen	0.54 × 0.40	1st seg: 0.20 × 0.25; 2nd: 0.36 × 0.25
Anal Laminae	0.17 × 0.11	0.21 × 0.10
Egg String (one specimen)	1.47	

species is related to any general pattern in the group.

Caligus elongatus Nordmann, 1832
Figs. 73–78

For a full description of adult female and male, synonymy, host records, and distribution, see Parker (1969). Measurements of *Caligus elongatus,* in millimeters, are given in Table 5.

Locality

Caligus elongatus was found at Port Hacking, New South Wales, Australia.

Host

The host animal is the balistid *Eubalichthys moaicus.*

Discussion

This is the first record of *Caligus elongatus* from the present host and the first record of it from New South Wales. This species has been previously recorded from Australia under the names *C. rapax* H. M. Edwards, 1840, by Heegaard (1962, p. 156) on *Raja* sp. from Tasmania and *Caligus rapax* Baird, 1850 by Kabata (1965, p. 120) from a host which is "presumed to be an elasmobranch from South Australian waters."

Since then Parker (1969) has extensively revised the species *C. elongatus* and shown that the previous Australian records together with most previous records of *C. rapax* should be recognized as belonging to *C. elongatus.*

Parker's description is very full and there is no purpose in redescribing the species here. However, one small point which was apparently overlooked by Parker is the extreme length of the postantennary spine in the male. In the female (Figs. 74 and 75) this spine is normally developed and reaches from its base about halfway to the second maxilla. In the male (Figs. 76 and 77) it is about twice as long (0.3 mm), its added length giving it a slender appearance, and it easily overlaps the second maxilla. Specimens, loaned by Dr. Z. Kabata, of *C. elongatus* from North Sea cod showed the same character. It can be expected to be found in other specimens of this species and may prove a useful character in identifying the male.

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